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High Performance DC Converter Designs With Controlled By A Simulink Software For Electric Motors

Hilmi Zenk
Department of Electrical-Electronics Engineering,
Engineering Faculty, Giresun University
Giresun, Turkey
hilmi.zenk@giresun.edu.tr

***Abstract*—*In this study, several different types of DC converters have been proposed to store the power generated by a solar panel in a 400W power pack and, if necessary, the energy stored in the battery can be easily applied to the same power on a permanent magnet DC motor. These high-performance DC-DC converters are available in Buck-Boost, Cúk and SEPIC types for speed control. Control of the system is provided by the controllers prepared in the widely used Matlab / Simulink digital environment. The communicator-computer communication is provided by the NI-PCI 6221 (37 Pin) card. The system has been tested with rapid response to performance changes.*

Keywords—DC-DC converter; buck-boost converter; Cúk converter; SEPIC converter; electric motor driver

1. INTRODUCTION

In most industrial applications, constant voltage DC source, variable voltage DC it needs to be turned into a source. A DC chopper, also known as DC-DC converters, converts DC directly to DC. A converter can also be thought of as an equivalent DC circuit for an AC transformer with a continuously variable winding rate. As the transformer can increase or decrease the AC voltage, the DC-DC converter can also increase or decrease the voltage value of a DC source [1]. Converters are used frequently in electric cars, marine freight elevators, forklift trucks, for controlling engine shots in mine hitter attractors. Soft speed control, high efficiency and dynamic response advantages such as DC-DC the reason for the preference of converters. It is also used to send the energy back into the material and also to actively braking the motors. This feature protects the energy in frequent stop transmission systems [2].

Conversion of the power from DC to DC is done with switched-mode power converters. Converters come from reactive elements and switches. The operating principle is achieved by setting the transmission and cutting times of the switches used in the circuit. If the frequency of the load-supplying voltage is large, DC power transmission is practically possible without interruption to the load. The satisfactory operation of such converters depends on the appropriate configuration of the reactive elements and the appropriate switching methods [3].

Switch mode DC-DC converters are nonlinear and time varying systems. The proper protection features of the converter application are stated together with the design criterion. The converters studied in this study were Buck-Boost, Cúk and SEPIC converters.

2. CONVERTER TYPES

2.1 Buck-Boost Converter

Buck-boost converters are commonly used in the regulation of DC power sources where the output is desired to be negative polarity relative to the common terminal of the input voltage, and where the output voltage may be less or more than the input voltage. This type of converter is achieved by connecting two converters of the drop and boost type. Output-to-input voltage conversion ratio in steady state; is the product of the conversion rates of the connected converters [4].

$$D\frac{1}{(1-D)}=\frac{V_0}{V_i} \qquad (1)$$

Equation (1) determines the duty cycle of the output voltage in relation to the input voltage. Such a connection is shown in Figure 1 a). When the switch is closed, the coil is energized but the diode does not conduct. When the switch is turned on there is no stored energy in the bobbin. In the steady state analysis investigated here, the value of the output capacitor is fixed is considered to be too large to provide an output voltage.

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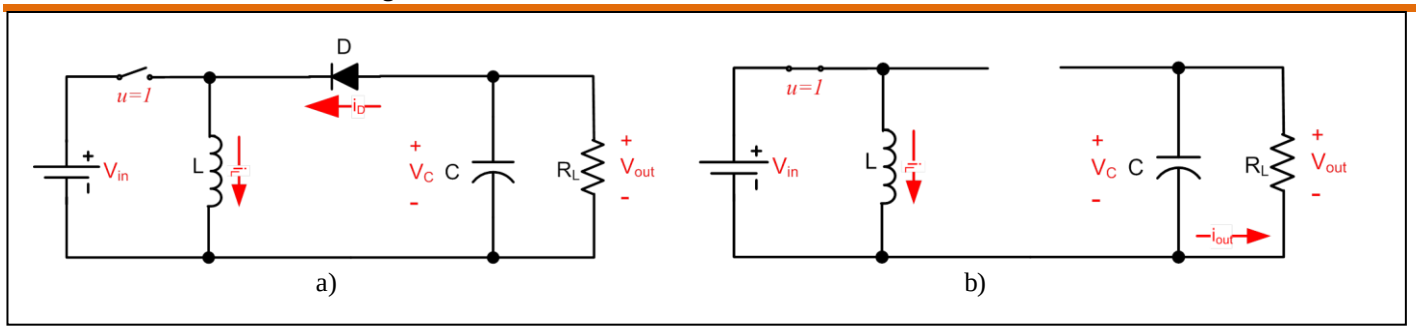

Fig. 1. *a) Simple circuit diagram of Buck-Boost converter b) Buck-Boost converter when switched ON position*

Figure 1. b) and Figure 2. a) shows the waveforms for continuous current continuous conduction mode of the coil current. By equalizing the integral (integral) of the coil voltage over a time period;

$$V_{in}DT_S + (-V_{out})(1-D)T_S = 0 \quad (2)$$

$$D\frac{1}{(1-D)}(P_{in} = P_{out}) = \frac{I_{0ut}}{I_{in}} \quad (3)$$

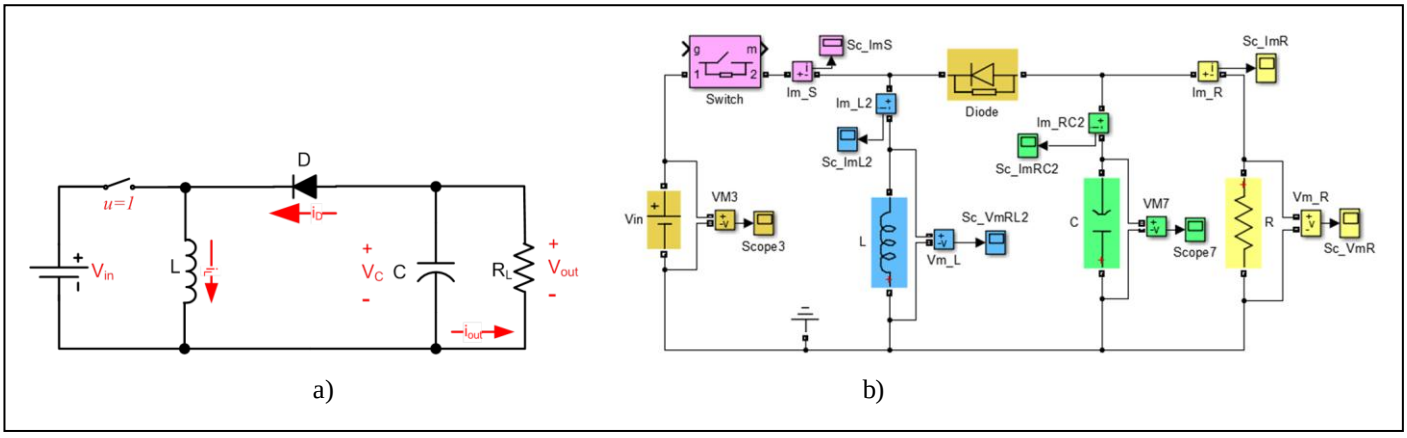

Fig. 2. *a) Circuit diagram of Buck-Boost converter when switched OFF b) Buck-Boost converter circuit MATLAB / Simulink equivalent.*

Figure 2. b) MATLAB / Simulink environment, a Buck-Boost converter circuit is prepared.

2.2 Cúk Converter

Cúk converter circuit connection shown in Figure 3. a). Converter circuit, the power switch is ideal, coils and capacitors losses and the DA is not an ideal voltage source V_{in} is the input source is assumed to be zero internal resistance. Figure 3. b) shows the MOSFET switch status of the new circuit to the case where transmission. In this case, completing the circuit of the DC source L_1, capacitor C_1 will discharge by transferring energy to the output. Figure 3. b) MOSFET switch position at the same time you are at the state of the diode circuit is new to the case where transmission. In this case, connect input capacitor C_1 starts charging. Circuit of Figure 6 is applied to the laws of Kirchhoff's voltage and current flows from the inductor and the capacitor voltage is equal to (4), (5), (6) and (7) are obtained.

$$v_{L1} = V_{in} \quad (4)$$

$$v_{L2} = -v_1 - v_2 \quad (5)$$

$$i_{C1} = i_2 \quad (6)$$

$$i_{C2} = i_2 - \frac{v_2}{R} \quad (7)$$

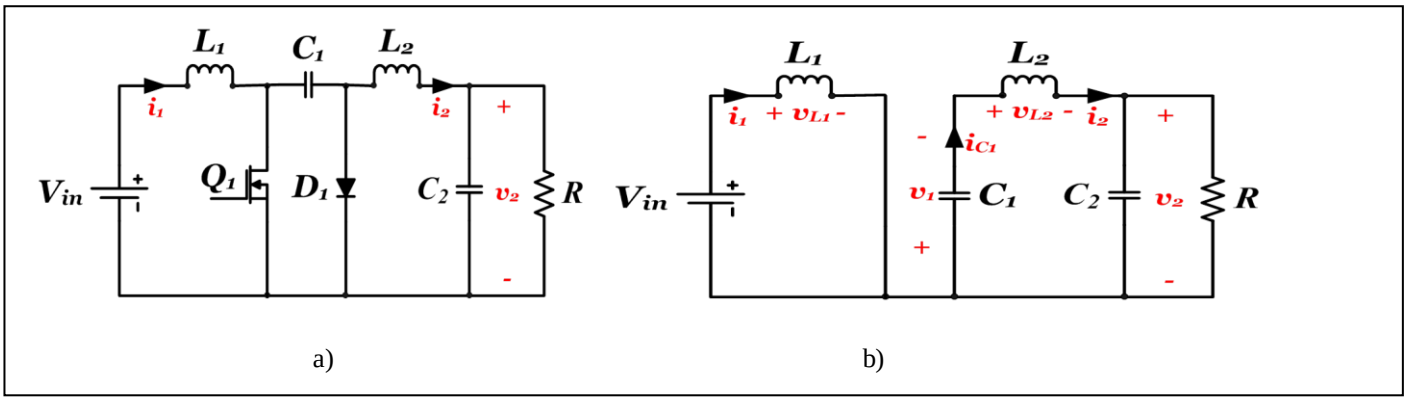

Fig. 3. *a) Simple circuit diagram of Cúk converter circuit b) MOSFET switch to the "ON" position.*

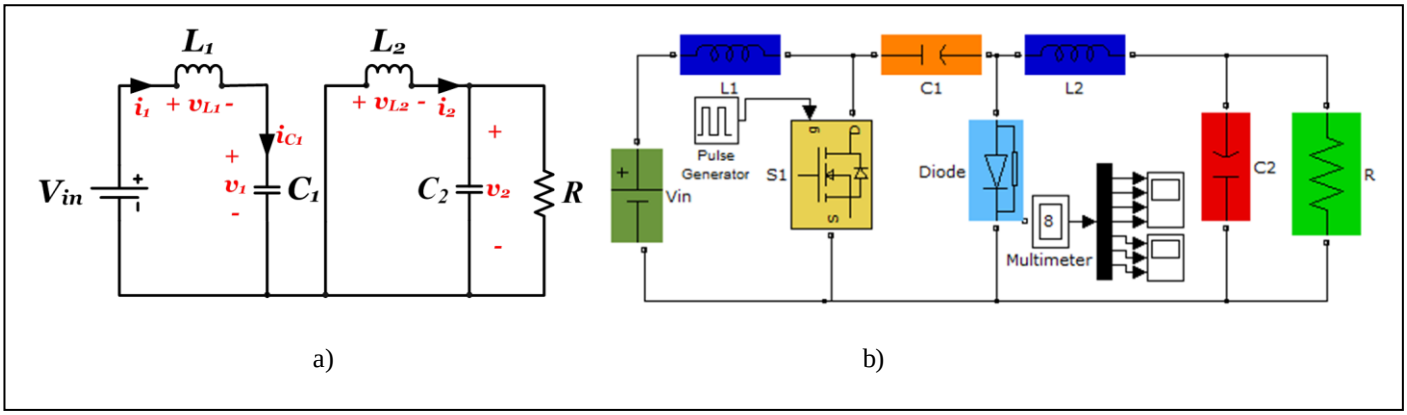

Fig. 4. *a) Cuk converter MOSFET switch to the "OFF" position.b) Cuk converter circuit MATLAB / Simulink equivalent.*

Figure 4. a) circuit is applied to the laws of Kirchhoff's voltage and current flows from the inductor and the capacitor voltage is equal to (8), (9), (10) and (11) are obtained.

$$v_{L1} = V_{in} - v_1 \quad (8)$$

$$v_{L2} = -v_2 \quad (9)$$

$$i_{C1} = i_1 \quad (10)$$

$$i_{C2} = i_2 - \frac{v_2}{R} \quad (11)$$

Figure 4. b) MATLAB / Simulink environment, a Cúk converter circuit is prepared. All the elements of the circuit in Figure 6, the time rate of flow and stress observed. 10V MOSFET source voltage of the switch corresponds to the case where the working rate of 75%, the output voltage is about 26V. In Figure 7, the voltage of about 2.5 V at the level of 25% of the working rate. As a result, Cúk converter switch duty cycle is greater than 50% of the output voltage increases, decreases when less than 50% [5].

2.3 SEPIC Converter

The single-ended primary inductance converter (SEPIC) is a DC/DC-converter topology that provides a positive regulated output voltage from an input voltage that varies from above to below the output voltage. It operates in continuous, discontinuous, or boundary conduction mode. SEPIC is controlled by the duty cycle of the control transistor. SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. As with other switched mode power supplies

specifically DC-to-DC converters, the SEPIC exchanges energy between the capacitors and inductors in order to convert from one voltage to another. A simple circuit diagram of a SEPIC converter is shown in Fig. 5.a), consisting of a coupling capacitor, C_1 and output capacitor, C_2; coupled inductors L_1 and L_2 and diode.

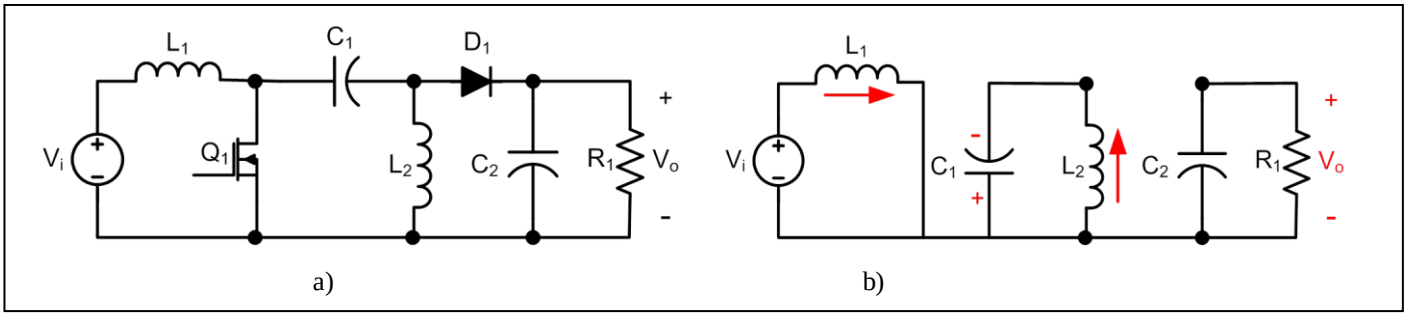

Fig. 5. *a) Simple circuit diagram of SEPIC converter, b) SEPIC converter MOSFET switch to the "ON" position.*

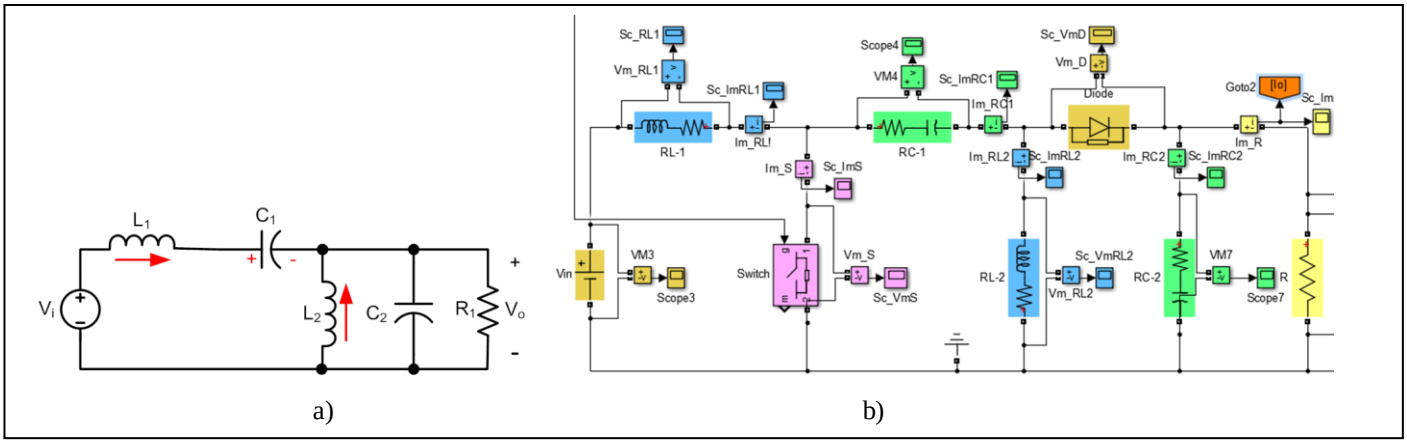

Fig. 6. *a) SEPIC converter MOSFET switch to the "OFF" position.b) SEPIC converter circuit MATLAB / Simulink equivalent.*

Figure 5. b) shows the circuit when the power switch is turned on. The first inductor, L_1, is charged from the input voltage source during this time. The second inductor takes energy from the first capacitor, and the output capacitor is left to provide the load current. No energy is supplied to the load capacitor during this time. Inductor current and capacitor voltage polarities are also marked [6]. When the power switch is turned off, the first inductor charges the capacitor C1 and also provides current to the load, as shown in Figure 6. b) The second inductor is also connected to the load during this time. The output capacitor sees a pulse of current during the off time, making it inherently noisier than a buck converter [7].

The formulae of duty cycles are given as follows

$$D_{\max} = \frac{V_0 + V_D}{V_{i(\min)} + V_0 + V_D} \qquad (12)$$

$$D_{\max} = \frac{V_0 + V_D}{V_{i(\max)} + V_0 + V_D} \qquad (13)$$

Figure 12 MATLAB / Simulink environment, a Cúk converter circuit is prepared.

3. System Control Loop

The converters are controlled with a voltage mode control scheme. The PWM module is configured for all converters mode with an independent time-base. The DC Link voltage is measured by the voltage sensors and sent to DSP control. This value is subtracted from the voltage reference in software to obtain the voltage error. The voltage error is then fed into a control algorithm that produces a duty cycle value based on the voltage error, previous error, and control history. The output of the control algorithm is also clamped to minimum and maximum duty cycle values for hardware protection. The voltage mode control algorithm must be executed at a fast rate in order to achieve the best transient response. Therefore, the control algorithm is executed in the ADC interrupt service routine,

which is also assigned the highest priority in the UPS code [8]. A block diagram of the push-pull converter control scheme is shown in Figure 13.

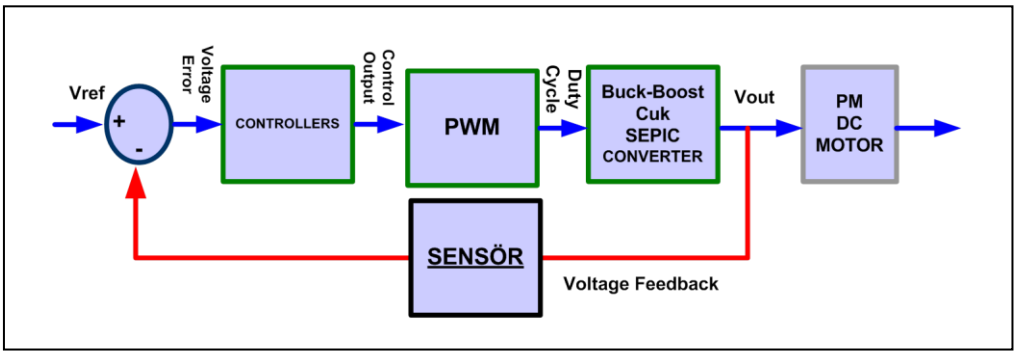

Fig. 7. *A Block diagram of converters voltage control loop*

4. Simulation Of The Full Systems

Figure 8. shows the connection of all the converters to the PMDC motor separately. For the analysis of the converters, the converter output current, output voltage and PMDC motor speed were examined at different D values.

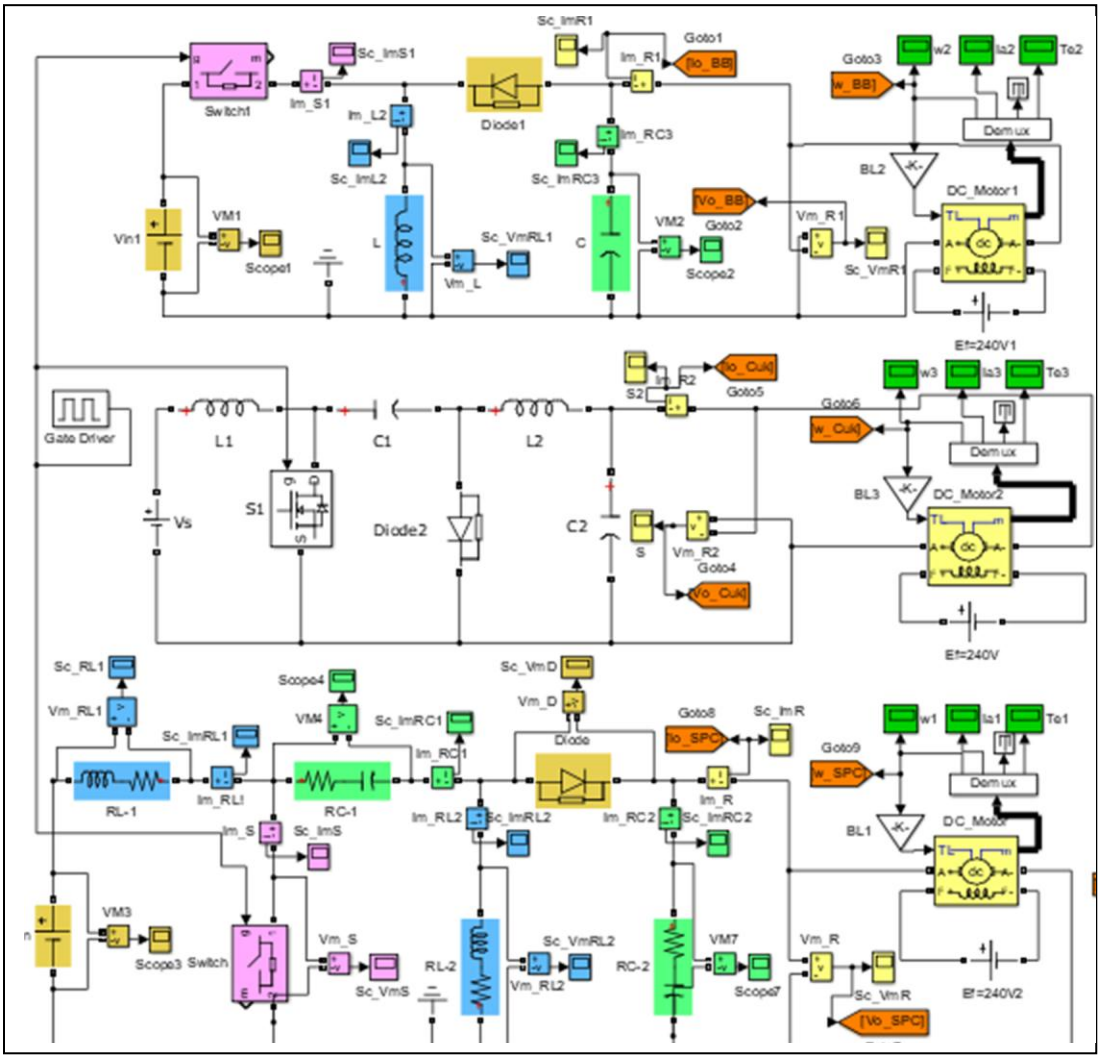

Fig. 8. *The block diagram of the whole system*

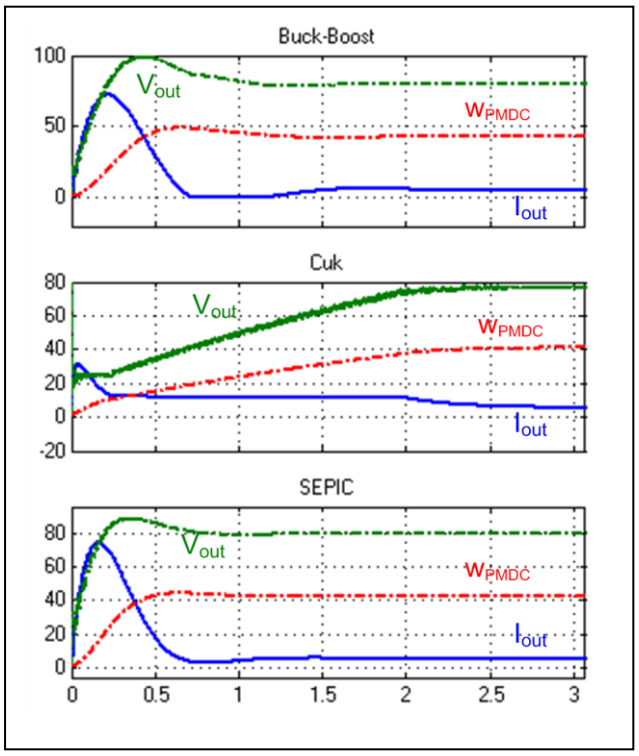

Fig. 9. *The block diagram of the whole system*

Figure 9. shows the response of the converters to the parameters at D = 0.25. Accordingly, the Buck-Boost converter parameters are; seating time = 2s, Vout = 80V, Iout = 5.22A and wPMDC = 42.58rad/s. Cúk Converter parameters; seating time = 2.5s, Vout = 77V, Iout = 5.37A and wPMDC = 41.14rad / s.The SEPIC converter parameters are measured as: slew time = 1.5s, Vout = 79.5V, Iout = 5.37A and wPMDC = 42.30rad/s. For D = 0.25 the Buck-Boost converter gave the best results.

Figure 10. a) shows the response of the converters to the parameters at D = 0.50. Accordingly, the Buck-Boost converter parameters are; seating time = 3.5s, Vout = 240V, Iout = 5.22A and wPMDC = 127.87rad/s. Cúk Converter parameters; seating time = 15s, Vout = 170V, Iout = 5.37A and wPMDC = 90rad/s.The SEPIC converter parameters are measured as: slew time = 1.5s, Vout = 237V, Iout = 5.37A and wPMDC = 126.3rad/s. For D = 0.50 the SEPIC converter gave the best results.

Figure 10. b) shows the response of the converters to the parameters at D = 0.75. Accordingly, the Buck-Boost converter parameters are; seating time = 8s, Vout = 718V, Iout = 48.7A and wPMDC = 383rad/s. Cúk Converter parameters; seating time = 3s, Vout = 226V, Iout = 46.5A and wPMDC = 119rad/s.The SEPIC converter parameters are measured as: slew time = 17s, Vout = 1145V, Iout = 77.72A and wPMDC = 611rad/s. For D = 0.75 the Cúk converter gave the best results.

5. Conclusion

The results were again very good in parallel with the unchecked situation. These controllers have successfully been successfully applied to a permanent magnet DC motor.

6. Acknowledgment

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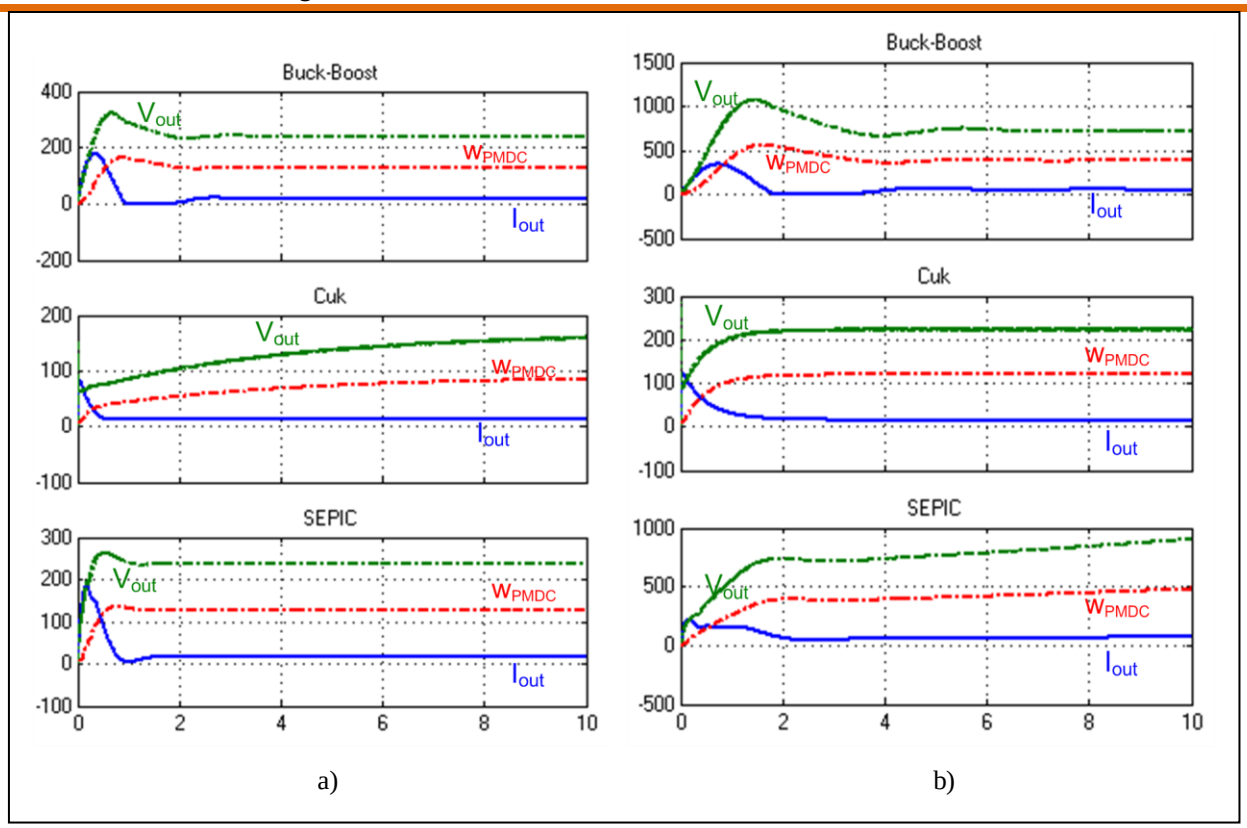

Fig. 10. *D=0,50 parameters of the converters*

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Authors

Hilmi Zenk, was born in Giresun, Turkey, he graduated from the Dumlupınar University, in Kütahya. He worked in TEDAŞ (Turkey Electricity Distribution Corparations) in Giresun. He is working a Lecturer at the Electrical - Electronics Engineering Department, Engineering Faculty, Giresun University. He received his Ph.D. from the Department of Electrical and Electronics Engineering, Karadeniz Technical University (KTÜ) in Turkey.